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September 3, 1998

Ms. Magalie Roman Salas
Secretary Federal Communications Commission
1919 M Street, N.W.
Room 222
Washington, D.C. 20554

Re: MM Docket No. 97-217

Dear Ms. Salas:

The accompanying request for declaratory ruling, filed with the Commission on August 19, 1998, raises issues directly related to the above-referenced docket. Accordingly, please associate this document with the above-referenced docket and direct any questions regarding this submission to me.

Sincerely,

J. Thomas Nolan

JTN/kd

Enclosure

Before the

Federal Communications Commission

Washington, D.C. 20554

In the matter of	)	
	)	
Request for Declaratory Ruling to	)	
Permit the Use of QPSK, OQPSK, and	)	File No. _____
MSK Modulation Techniques	)	
on Frequencies Allocated to the	)	
Instructional Television Fixed Service (ITFS)	)	
and Multipoint Distribution Service (MDS)	)	

To: Chief, Mass Media Bureau

REQUEST FOR DECLARATORY RULING

PACE Telecommunications, by its attorneys and pursuant to Section 1.2 of the Commission's Rules, hereby requests that the Commission issue a declaratory ruling to authorize the use of Quadrature Phase Shift Keying (QPSK), Offset Quadrature Phase Shift Keying (OQPSK), and Minimum Shift Keying (MSK) in a manner otherwise consistent with Parts 21 and 74 of the Commission's Rules and relevant Orders upon application by MDS or ITFS licensees. Issuance of the requested ruling will permit the use of ITFS and MDS channels for high speed digital video and data transmission at a fraction of the cost of currently authorized equipment. The results of extensive field testing in support of this request are attached hereto as Exhibit A.

I. Need for a Declaratory Ruling

PACE is a consortium of school districts, universities, and government entities in Northern Michigan. PACE operates a distance learning facility that uses ITFS frequencies to transmit locally

developed program material to approximately 20,000 students in a six-county area. The area is rural, sparsely populated, and academically underserved, and PACE has been at the forefront of an initiative to bring the benefits of advanced technology to the schools. As part of that initiative, PACE wishes to deploy an interactive, two-way communications network for the transmission of video and other information between the schools based on digital modulation used with its licensed ITFS frequencies. However, the Commission's current orders authorizing digital operation are inadequate to permit the kind of deployment that PACE envisions.

The Commission currently permits the routine authorization of Quadrature Amplitude Modulation and Vestigial Sideband (VSB) modulation for use on ITFS and MDS frequencies.[1] These modulation techniques are designed to allow high-bandwidth applications such as multiplexing multiple video streams or serving dozens of subscribers to an interactive data service simultaneously on a single 6 MHz video channel. However, the encoding and decoding equipment used to implement these modulation techniques is prohibitively expensive for rural school such as those PACE serves. Moreover, PACE has no need for the tremendous bandwidth that QAM and VSB provides. PACE's goal is far more modest -- to transmit a single digitized video stream at a data rate of 4 megabits per second on an ITFS channel. The modulation techniques for which PACE seeks approval are designed to provide this functionality using equipment that can be produced at a fraction of the cost of QAM and VSB equipment.

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1. Request for Declaratory Ruling on the Use of Digital Modulation by Multipoint Distribution Service and Instructional Television Fixed Service Stations, *Declaratory Ruling and Order*, 11 FCC Rcd 18839 (1996) ("Digital Declaratory Ruling").

QPSK modulation offers robust transmission and reception characteristics, while simplifying encoder and decoder design, and consequently is a good choice for the low-cost equipment PACE desires to deploy.[2] Authorization for OQPSK and MSK is also sought at the same time because these techniques may be preferred over QPSK by some transmission equipment suppliers as these modulations may be part of their product line, be more cost-effective, or have perceived performance benefits for some applications. OQPSK can be used in conjunction with some transmission equipment that, because of bandwidth limitations, does not maintain the spectral purity of QPSK-modulated signals. While one option is replacement of the bandwidth-limited components with equipment that is compatible with QPSK, a more cost-efficient approach may be to modulate the signal using OQPSK.

An MSK-modulated signal is predicted to produce a flat power spectral density across the occupied transmission bandwidth. Even with completely randomized data, QPSK and OQPSK are not predicted to produce a flat power spectral density, and instead conform to a sin x/x shape.[3] Although the testing described below demonstrates that this degree of deviation from a flat power

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2. QPSK modulation is also the subject of a pending petition for declaratory ruling filed last December with the Commission. *See* Request for Declaratory Ruling on the Use of Code Division Multiple Access and Quadrature Phase Shift Keying Digital Modulation by Multipoint Distribution Service and Instructional Television Fixed Service Stations (filed Dec. 2, 1997). However, that petition did not provide any actual test results using QPSK modulation (although it offered a limited QPSK simulation). Instead, it argued that the Commission had already authorized the use of QPSK because QPSK is theoretically equivalent to 4-QAM, and hence is arguably within the scope of the Digital Declaratory Ruling. *Id.* at 5 and Appendix A at 3.

3. See Test Report, attached hereto as Exhibit A, at 5-6. The previous petition for declaratory ruling on the use of QPSK modulation failed to note this difference between QPSK and the previously authorized modulation techniques of QAM and VSB.

spectrum is not of concern, MSK modulation offers a substitute for QPSK if a flat power spectrum is necessary. However, the testing described below also demonstrates that MSK modulation is somewhat less robust than QPSK, producing a higher bit-error rate for equivalent signals.

II. Testing for Compliance with the Standard for Declaratory Ruling

The Commission granted the Digital Declaratory Ruling permitting the use of QAM (up to a modulation density of 64) and VSB (up to a modulation density of 8) based on tests of these modulation techniques conducted in 1995, the results of which were submitted in support of the request for declaratory ruling.[4] Those test results demonstrated that QAM and VSB could be implemented without causing interference to analog or other digital systems. The Commission stated that, while its declaratory ruling was limited to QAM and VSB, it remained open to future requests for similar declaratory rulings on other modulation techniques.[5] The Commission stated that "requesters would need to show that other modulation techniques could be used in a manner that would not interfere with MDS and ITFS analog and digital operations."[6]

On March 10, 1998, PACE was granted a developmental authorization for the purposes of testing new digital transmission equipment to enable two-way communications on ITFS frequencies. The developmental authorization permits PACE to deploy and test "upstream" transmitters at certain of its preexisting ITFS receive sites. From May 18 through May 28, 1998, under the authority of the developmental authorization, PACE and Summation Research, Inc. ("SRI") conducted field tests

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4. *See Report on Wireless Cable Interference Testing, April 27-May 4, 1995* (submitted with Petition for Declaratory Ruling, July 13, 1995.

5. Digital Declaratory Order, 11 FCC Rcd at 18848-49 (para. 14)

6. *Id.* at 18848 n.31.

of prototype digital modulation equipment manufactured by SRI using the QPSK, OQPSK, and MSK modulation techniques that are the subject of this request for declaratory ruling. The tests were designed to examine the compliance of the modulation techniques with the Commission's interim requirements, as set forth in the Digital Declaratory Ruling.

III. Test Results

The test report is summarized below and appended hereto as Exhibit A.

A. Digital-to-Analog TV and Analog TV-to-Digital Interference

The tests demonstrate that the Commission's current 45 dB and 0 dB ratios for co-channel interference and adjacent-channel interference are conservative at predicting interference from QPSK, OQPSK, and MSK modulated digital signals to NTSC analog television signals. For co-channel signals, threshold of visibility (TOV) -- in which the interfering digital signal is barely perceptible in the television picture -- occurred at a D/U ratio of 36.5 or lower.[7] A D/U ratio of 45 dB thus provides at least an 8.5 dB margin of assurance of no perceptible interference. This is better interference protection than that afforded by 64-QAM and 8-VSB in the testing that resulted in the Digital Declaratory Ruling approving those modulation techniques.[8]

For adjacent-channel signals, TOV occurs at a D/U ratio of -1 dB or lower.[9] A D/U ratio of 0 dB thus provides at least a 1 dB margin of assurance of no perceptible interference. This

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7. Test Report at 48, Table 4.2.2.1. A picture quality of CCIR 4 -- in which interference is "perceptible but not annoying" occurred at a D/U ratio at least 6 dB lower.

8. *See* Report on Wireless Cable Interference Testing April 27-May 4, 1995, at 25 (average D/U ratio at TOV between 44.0 and 47.4 for co-channel digital signal to analog NTSC).

9. Test Report at 49, Table 4.2.2.2. Again, a picture quality of CCIR 4 occurred at a D/U ratio at least 6 dB lower.

performance demonstrates comparable interference protection to that afforded by 64-QAM and 8-VSB in the testing that led to the Digital Declaratory Ruling.[10]

The tests also demonstrate that the Commission's current 45 dB and 0 dB ratios are sufficient to guarantee reception of QPSK, OQPSK, and MSK modulated digital signals in the presence of interference from analog NTSC television. For co-channel signals, a bit-error rate (BER) of 10^{-6} was achieved at a D/U ratio of 37 or less.[11] A D/U ratio of 45 dB thus provides at least an 8 dB margin of assurance of reasonably error-free reception of digital data. For adjacent-channel signals, tests were not representative of actual performance because the prototype ITFS receiver had inadequate dynamic range or FM demodulation performance to receive digital data in the presence of analog interference.[12] The test results do not justify any change to the D/U ratio of 0 dB, since the problem will be corrected with improved receiver design.

B. Emission Mask

The QPSK, OQPSK, and MSK modulation equipment was operated for the tests under the Commission's interim requirement for measuring digital power level, *i.e.*, average power equal to peak video power.[13] The testing demonstrated that the equipment performed within the

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10. *See* Report on Wireless Cable Interference Testing April 27-May 4, 1995, at 27-28 (average D/U ratio at TOV between 0 and -6.6 for adjacent-channel digital signal to analog NTSC).

11. Test Report at 49, Table 4.3.1.

12. Test Report at 50, Table 4.3.2.

13. *See* Test Report at 46; Digital Declaratory Ruling, 11 FCC Rcd at 18855-56 (para. 27).

Commission's interim out-of-band emission limitations[14] (with one minor exception that will be corrected in future hardware revisions).[15]

The Commission's interim requirements for digital modulation also include a requirement that the power spectral density be "substantially uniform" across the occupied bandwidth of the transmitted signal.[16] The Commission states that this requirement of substantial uniformity may be accomplished through the use of data randomization to avoid "symbol patterns" that could cause peaks in the digital power spectrum.[17]

Testing of the SRI equipment demonstrates that, as theoretically predicted, the power spectral density of an MSK-modulated signal is approximately flat across the occupied bandwidth. However, again as theoretically predicted, the power spectral density of QPSK- and OQPSK-modulated signals conform to a sin x/x shape, with a broad peak in the center of the occupied bandwidth that is approximately 6 dB above the average power spectral density. The tests were performed with random data. Thus, although data randomization can assure that no deviation from the sin x/x shape occurs, randomization cannot remove the broad peak of the sin x/x waveform itself.

Because QPSK and OQPSK modulation have been demonstrated to provide protection to co- and adjacent-channel analog and digital signals when the Commission's 45 and 0 dB D/U ratios are used, and because of the important benefits that can be achieved through the use of these modulation techniques, the testing supports the adoption of a standard for "substantially uniform"

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14. *See* Digital Declaratory Ruling, 11 FCC Rcd at 18852-55 (para. 21-25).

15. Test Report at 46 (the 40 MHz clock rate will be removed from the transmitter output).

16. Digital Declaratory Ruling, 11 FCC Rcd at 18857-58 (para 30).

17. *Id.*

power spectral density that will permit the use of these modulation techniques. Specifically, the Commission should clarify that

> Spectral flatness shall be such that nowhere in the channel will the spectral density exceed the average spectral density (peak video power divided by channel bandwidth) by more than 6 dB.[18]

III. Conclusion

The attached test report demonstrates that QPSK, OQPSK, and MSK modulation can be routinely authorized for use with ITFS and MDS frequencies. The Commission should issue a declaratory ruling that ITFS licensees may operate using QPSK, OQPSK, and MSK modulation in accordance with the requirements and the procedures set forth in the Digital Declaratory Ruling as clarified herein.

Respectfully submitted,

PACE TELECOMMUNICATIONS

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Its attorneys

Dated August 19, 1998

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18. Test Report at 46-47.

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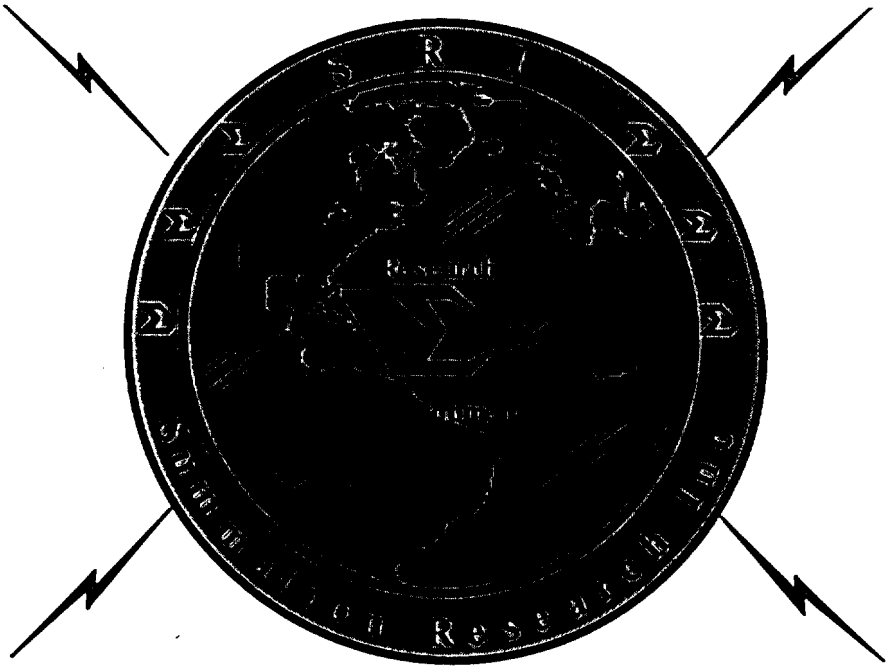

Prepared For
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Date: July, 1998

Document Number 97-179-003

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Any opinions, findings, and conclusions or recommendations expressed in this material are those of PACE Telecommunications and Summation Research Inc. and do not reflect the views of the National Science Foundation.

ITFS PACE INITIATIVE

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for
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INTERNET TO THE SCHOOLS

FIELD TESTS

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ITFS PACE INITIATIVE

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ACKNOWLEDGEMENTS

Summation Research, Inc. (SRI) would like to acknowledge and thank the following organizations and individuals for their commitment to the ITFS PACE Initiative for providing low cost Internet and other data services to the school children/staff of the Cheboygan-Otsego-Presque Isle Intermediate School District. Specifically, the support and/or participation in the PACE field testing of ITFS Digital Data Transmission conducted during late May is recognized.

PACE Telecommunications Consortium

"Providing Academics Cost Effectively" (PACE) has been the hallmark of PACE since its inception. Under the able leadership of Mr. Jack Keck, Director, this recent ITFS PACE Initiative for Digital Data Transmission to enhance the Internet and interactive TV services to the schools will enable PACE to continue to provide quality services to their clients. PACE provided funding and technical support for this testing effort.

Mr. David Mania, PACE Engineering, was instrumental in forging the SRI–PACE relationship; in the direction, logistics and early planning of the Field Tests; and in the actual conduct of the testing. His understanding of the PACE ITFS system and his commitment to task and working to accomplish all of the necessary testing in the allocated time was most helpful.

Mr. Mike Perri, PACE Engineering, was instrumental in the overall conduct of the field testing. His understanding of the PACE ITFS transmission system as well as the existing Ethernet structure was invaluable. Mike made most of the spectral plots found in this report. His knowledge, enthusiasm, and dedication were most helpful.

Cheboygan-Otsego-Presque Isle Immediate School District

In addition to providing the need for the capabilities being evaluated, the Immediate School District provided funding support for this effort.

Wolverine Community Schools

Wolverine Elementary School, particularly Ms. Susan van den Hoek's classroom, hosted over three days of performance and compatibility testing. We attempted to work around their schedule but they were most supportative of our testing and strongly supported the need for improved Internet access.

Pellston Community Schools

Superintendent William Tebbe assured the support of his schools in our testing and strongly supported the need for improved Internet access.

Summation Research, Inc.

Engineering support for this test initiative was provided by Bill Queen and Jerry Howe of SRI Engineering. SRI also provided these engineering services at cost with no fee.

National Science Foundation

Financial support provided by the National Science Foundation was critical to this test effort. Support of efforts like this will go a long way toward providing low cost Internet services to America's rural schools.

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ABSTRACT

This ITFS PACE Initiative for providing low cost Internet and other data services to the school children/staff of the Cheboygan-Otsego-Presque Isle Intermediate School District is one of several approaches being investigated by PACE toward meeting current and future wideband data requirements for their client schools and their young, creative students. This report documents the overall test effort to determine the suitability of using the standard ITFS TV spectrum for providing low cost wideband data services between PACE clients and to/from their Internet Service Provider.

The PACE community and other rural educational organizations have the need to cost effectively provide wideband data services to their remote school sites. Internet access, compressed video for distance learning and other informational services are mandatory for the 21st century learning environment.

This report conclusively demonstrates the viability of using ITFS communications to satisfy wideband digital data communications needs within the ITFS licensee community. The existing ITFS infrastructure provides a solid foundation for providing, cost effectively, the means, methods, and technology for rural educational communities to provide their clients access to information age resources. PACE (Providing Academics Cost Effectively) continues to follow this mandate for the school districts of nothern lower Michigan.

All field testing was performed within a forty mile radius of Indian River, Michigan, the headquarters of the PACE Telecommunications Consortium. All testing was performed in compliance with the PACE obtained FCC Developmental Broadcast Authorization, dated March 10,1998.

Performance (i.e. Bit Error Rate-BER) testing was accomplished over four different ITFS communications links including two multi-hop links. Modulations tested included Minimum Shift Keying (MSK), Quadrature Phase Shift Keying (QPSK), and Offset Quadrature Phase Shift Keying (OQPSK). Data rates tested included 4 Mbps, 2 Mbps, 250 Kbps, and 128 Kbps. In some instances, data encoding (Viterbi, k=7, r=1/2) was tested in the ITFS environment.

Testing was also performed to determine the compatibility of these communications to the FCC requirements in the current FCC Notice of Proposed Rulemaking, FCC 97-360, dated October 10, 1997. Particularly, the power levels, spectral masks, and spectral density of the transmitted signal were assessed. Interference of the digital transmissions with the standard ITFS TV transmission for cochannel and adjacent (upper, lower and upper/lower) channels was evaluated in the field environment. Additionally, to aid in the digital equipment development, the adjacent and cochannel TV interference with the digital transmissions was assessed.

The equipment used for the digital communications was the Summation Research, Inc (SRI) ITFS Receiver for receiving and the SRI ITFS Modulator and existing, PACE owned, ITFS Power Amplifier(s) for transmitting. The SRI equipment was a modification to standard SRI Satellite Communications Receivers, Modulators, and Exciters developed for military applications. The resulting ITFS equipment used in this testing was a direct result of technology transfer from Military S-Band Satellite communications technology. Transfer of the Digital Signal Processing and RF modulation technology was critical to the adaptability and performance of these products for digital ITFS communications.

Some conclusions from the digital communications testing over existing PACE transmission links follow:

- All wideband transmission modes tested- MSK (4 Mbps, 2.7 Mhz) QPSK(4Mbps),OQPSK(4 Mbps), and BPSK(2Mbps)- at full digital power over both point to point links provided excellent bit error rate (BER) performance. For these links, full digital power provides over 15 dB of link margin without degradation of BER.
- Viterbi encoding worked well in the PACE ITFS environment and improved performance by about 4 dB at the expense of ½ the data rate.
- MSK modulation at 4 Mbps data rate with a frequency deviation of 2.7 Mhz (m=0.675) performed quite acceptably. This transmission spectrum was most compatible with the flat spectrum requirement. The BER performance was as predicted with an increased S/N of 3 dB required for compatible performance with QPSK/OQPSK.

- QPSK modulation at 4 Mbps data rate performed quite acceptably. The transmission spectrum was the standard Sin X/X -truncated by channel filtering. Performance was near theory for the noise environment.
- OQPSK modulation at 4 Mbps data rate performed quite acceptably. The transmission spectrum was the standard Sin X/X -truncated by channel filtering. Performance was near theory for the noise environment.
- Testing clearly supported a 4 Mhz data rate transmission with approximately 18dB of link margin (15dB for MSK) for maximum digital power.

Narrowband testing was undertaken to support channelization of ITFS signals such that more point to point users could be serviced within the ITFS spectrum. Testing was accomplished at 128 Kbps or 250 Kbps. Maximum power for narrowband was set to that which would be consistent with the power density spectrum allowed for wideband digital communications.

- All narrowband (128 Kbps and 250 Kbps) transmission modes tested-MSK (128 Kbps, 100 Khz; 250 Kbps, 200Khz) QPSK, OQPSK, and BPSK at full narrowband digital power over the Bear Creek to Wolverine point to point link provided excellent bit error rate (BER) performance.
- Narrowband communications link performance for the MSK, and QPSK is consistent with theory with MSK requiring 3 dB more S/N to achieve the same performance as QPSK.
- Testing clearly supported a 128 Kbps data rate transmission with about a 20dB link margin (17dB for MSK) for "maximum" (i.e. In this case 14, dB below the wideband digital power) narrowband digital power.
- Channelized narrowband digital operation within the standard ITFS channel is feasible.

The conclusions drawn from this testing program on FCC related compatibility issues are as follows:

- The current Desired/Undesired (D/U) interference protection ratio's for cochannel and adjacent channel operations are acceptable for MSK and QPSK type signals.
- The current spectral mask (i.e. –38dB at channel edge and linearly decreasing to –60dB at the middle of the adjacent channel) is acceptable for MSK and QPSK type signals.
- The current overall power constraint of average digital power being equal to or less than the peak video power is acceptable for MSK and QPSK type signals.
- PACE would suggest that the digital transmission spectrum be defined as follows:

- Total digital power within a channel shall be equal to or less than the peak Video power (PVP) allowed. This results in an average spectral density of PVP/6 Mhz (dBm/Hz) for the digital modulation. This is the same as currently authorized.
- The "substantially flat" spectrum requirement be defined as follows "Spectral flatness shall be such that no where in the channel will the spectral density exceed the average spectral density by 6 dB. This would apply to single or channelized operation"

In summary,

- Test results have clearly supported the PACE objectives for utilization of ITFS resources for meeting school/staff wideband data communications needs. Results were exceptional in that wideband downstream communications using any of three modulations over four different PACE links were successfully demonstrated. For upstream communications, narrowband transmissions were readily supported as long as the downconverters were stable. Waveforms were demonstrated to be consistent with FCC requirements and none caused interference when the current desired/undesired (D/U) interference protections were satisfied. The existing PACE ITFS Infrastructure will readily accommodate new digital communications capabilities.
- This testing clearly demonstrates that MSK, QPSK and OQPSK wideband modulations can be effectively utilized for digital data transmission without causing any adverse effects to ITFS communications. Recommend that MSK, QPSK, OQPSK or any other modulation meeting the spectral characteristics defined herein be approved by the FCC for use in digital transmission over ITFS channels.
- This testing clearly demonstrates that MSK, QPSK and OQPSK narrowband modulations can be effectively utilized for digital data transmission without causing any adverse effects to ITFS communications. Recommend that channelization of any ITFS channel be approved by the FCC as long as the spectrum characteristics do not peak at more than 6 dB above the average power spectral density.
- PACE should proceed with the implementation of a system using the demonstrated technologies to serve as a "Beta Test Site" for providing wideband informational services to its client.

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(Continued)

APPENDIX A

1.0 INTRODUCTION

1.1 Objective

The objective of this testing is to determine the field performance of MSK and other modulations over PACE Operational ITFS Communications Channels. This will help determine the suitability of these modulations for wideband (4 Mbps) digital data transmission downstream to intra-school computer networks, interactive TV, and data transmission upstream from these same networks at 128Kbps or higher data rates thus supporting the Asymmetrical Data transmission mode consistent with Internet access.

1.2 Scope

The scope of this Test Report is to document the test results from the field test effort of the SRI ITFS developmental modulator and demodulator for MSK modulation over PACE operational ITFS communication channels and to document the TV-Digital Data Transmission compatibility in a real world environment. For the supporting ITFS Laboratory test results see the summary in Appendix A of this report.

1.3 Field Testing

The field testing will evaluate true link performance as compared to that expected from the Laboratory tests and address compatibility with existing ITFS TV communications. Specifically,

- LINK PERFORMANCE- Three or more different physical links will be tested providing as much technical and physical diversity as possible. Bit error rate (BER) testing will be the sole measure of link performance. It will be determined under the circumstances of maximum permissible digital power, at power levels permitting 10E-7 BER performance, and at power levels permitting 10E-5 BER. Different data rates, encoded (Viterbi, constraint 7;rate1/2 as provided by ITFS Receiver, and ITFS Modulator), or unencoded, MSK modulation and others (BPSK, QPSK, OQPSK) were tested.

- COMPATIBILITY- This testing- at 4 Mbps and 128 (or 250) Kbps - verified that the transmitted signals characteristics were within the requirements of the FCC with respect to digital transmission over ITFS. That is, the parameters as defined in FCC 97-360 (Reference D) of October 10,1997 were evaluated. Secondly, compatibility testing determined when adjacent channel (upper, lower, upper & lower) and co-channel interference with digital signals was observable and objectionable by PACE test personnel.